



Observations of bursting coherent synchrotron radiation in the ALS

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Overview

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- What is CSR?
- Challenges for generating CSR
- ALS studies
- First evidence for stable CSR
- A dedicated ring for coherent far-IR
- Plans

Coherent Synchrotron Radiation



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Coherent emission scales with N^2 .

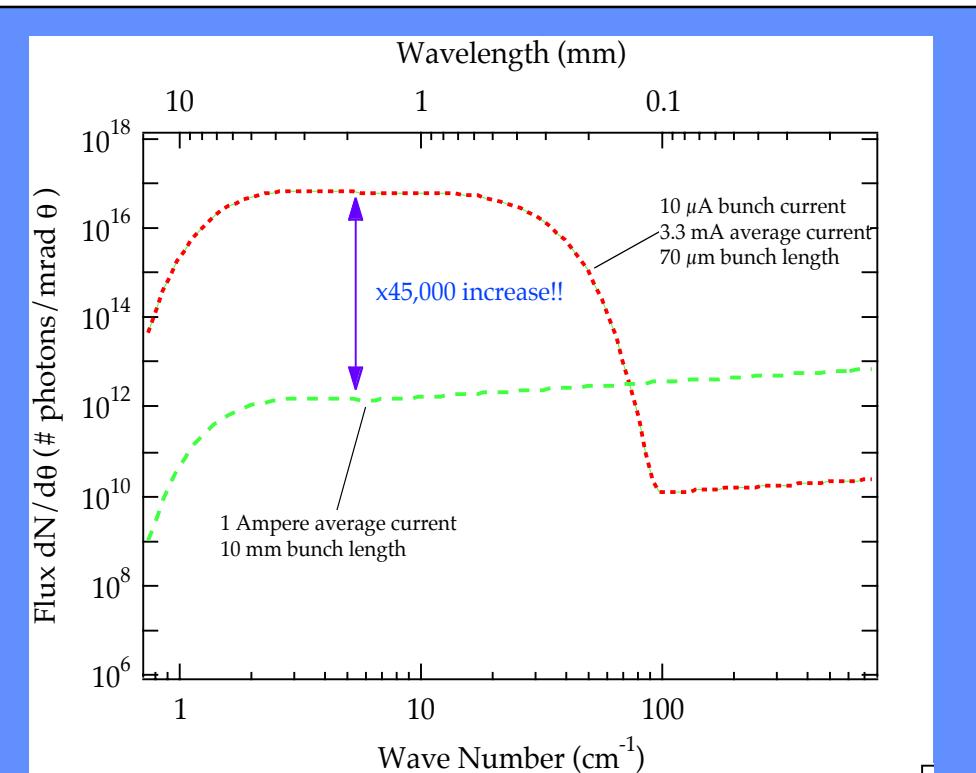
$$P(\omega) = p(\omega) [N + N(N-1)g(\sigma_i)]$$

INCOHERENT

COHERENT

For a gaussian bunch distribution, CSR occurs in free space when: $\pi\sigma < \lambda$

Broadband coherent emission for the range $100 \mu\text{m} < \lambda < 1 \text{ mm}$ would be a powerful and unique source of radiation.



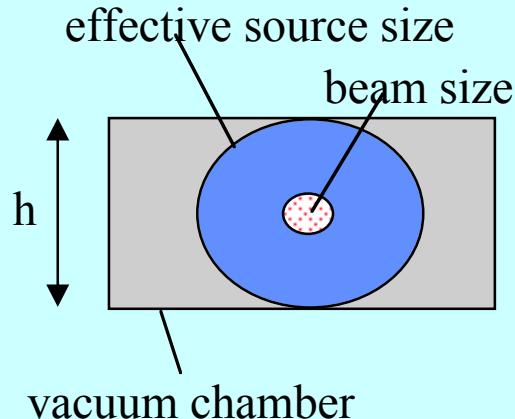
Factor 45,000 increase in coherent mode with 1.4×10^7 electrons at 1 THz over 1 Ampere conventional mode.

Challenges for generating CSR



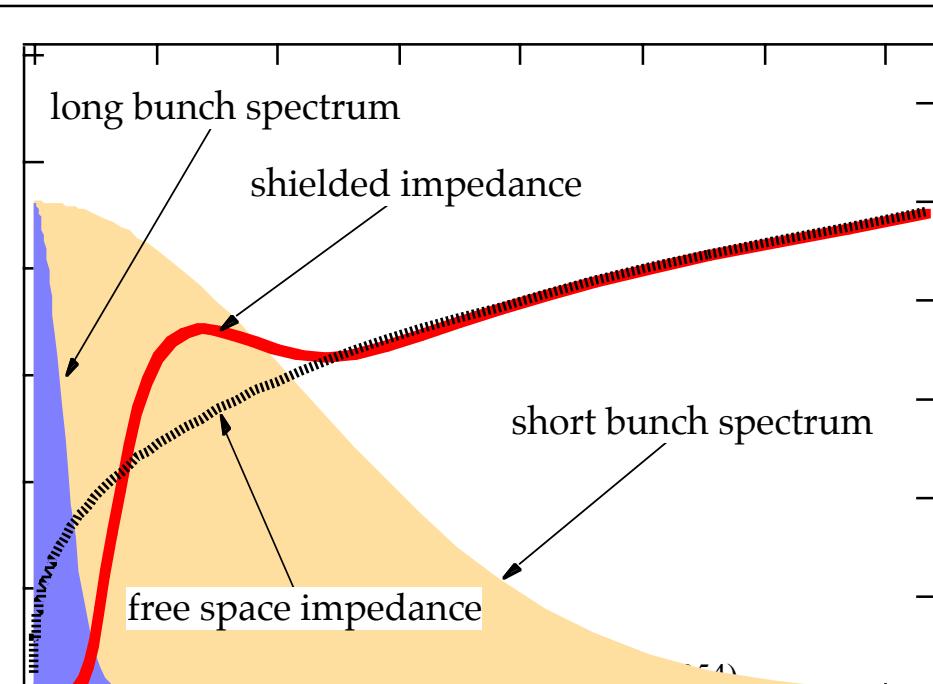
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Vacuum Chamber acts as a High Pass Filter



When the effective size of the SR source is equal to the height of the vacuum chamber, SR is suppressed.

Most rings do not have short enough bunches to generate CSR!



Frequency
Shielding by the vacuum chamber limits the SR emission to wavelengths above the waveguide cutoff condition

$$\pi\sigma < \lambda < 2h\left(\frac{h}{\rho}\right)^{1/2}$$

ALS Experimental setup



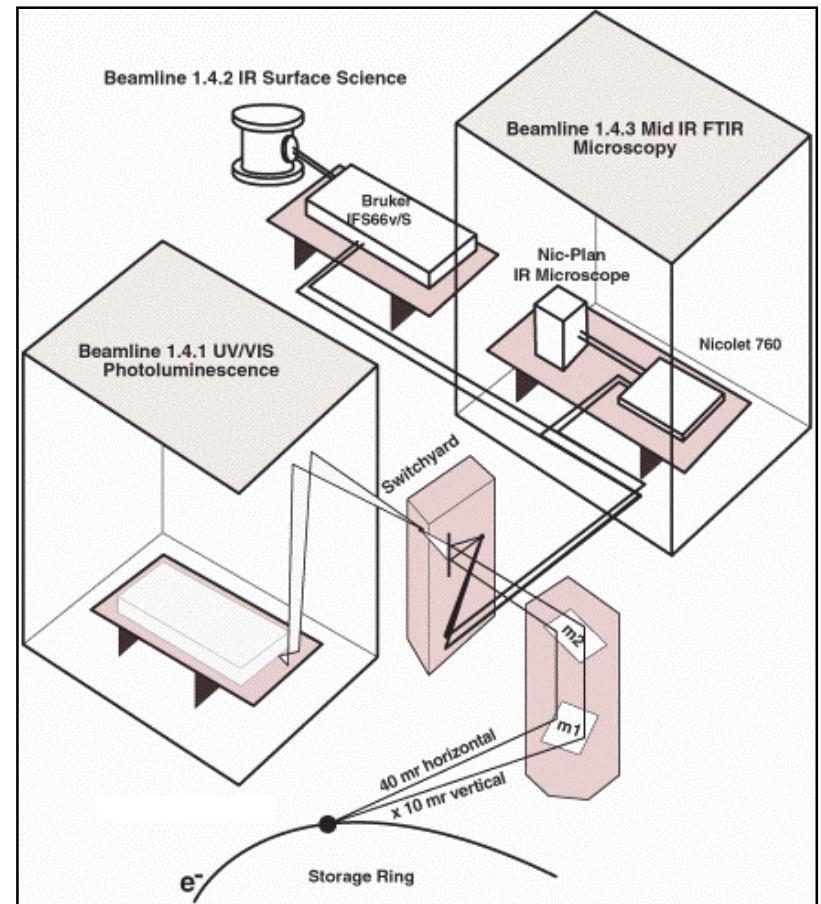
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ALS IR studies Group

- Michael Martin, LBNL
- John Byrd, LBNL
- Fernando Sannibale, LBNL
- Wayne McKinney, LBNL
- Agusta Loftsdottir, LBNL/UC Davis

Collaborations with:

- Larry Carr, NSLS-BNL
- Jim Murphy, NSLS-BNL
- Gennady Stupakov, SLAC
- Wim Leemans, LBNL
- Bout Marcelis, LBNL/Eindhoven
- Marco Venturini, SLAC
- Bob Warnock, SLAC
- ALS AP and operations group



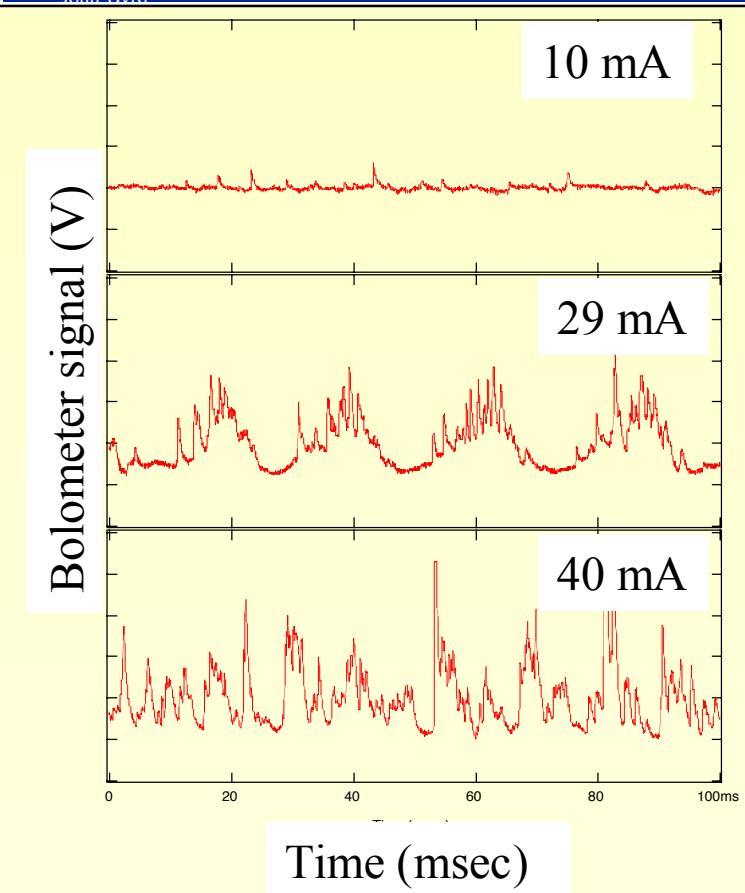
Schematic view of ALS BL1.4

- 7 meter from source
- diamond vacuum window for mid-IR transmission
- optical SR beam for alignment
- existing diagnostic tools

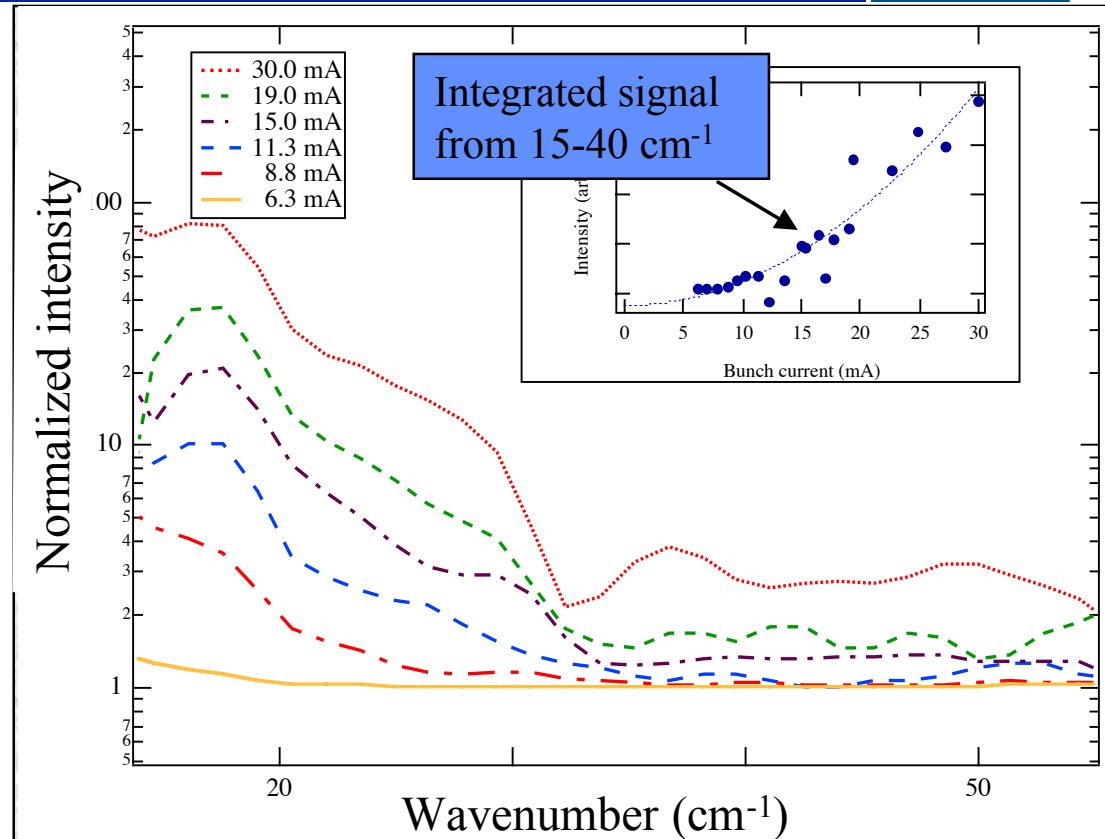
Coherent FIR Bursts at ALS



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Bursts of far-IR CSR observed on a bolometer. Threshold depends on beam energy, bunch length, energy spread, and SR wavelength.



FTIR spectral data shows strong increase below 35 cm^{-1} (300 microns). Integrated signal shows a quadratic increase, confirming coherent radiation.



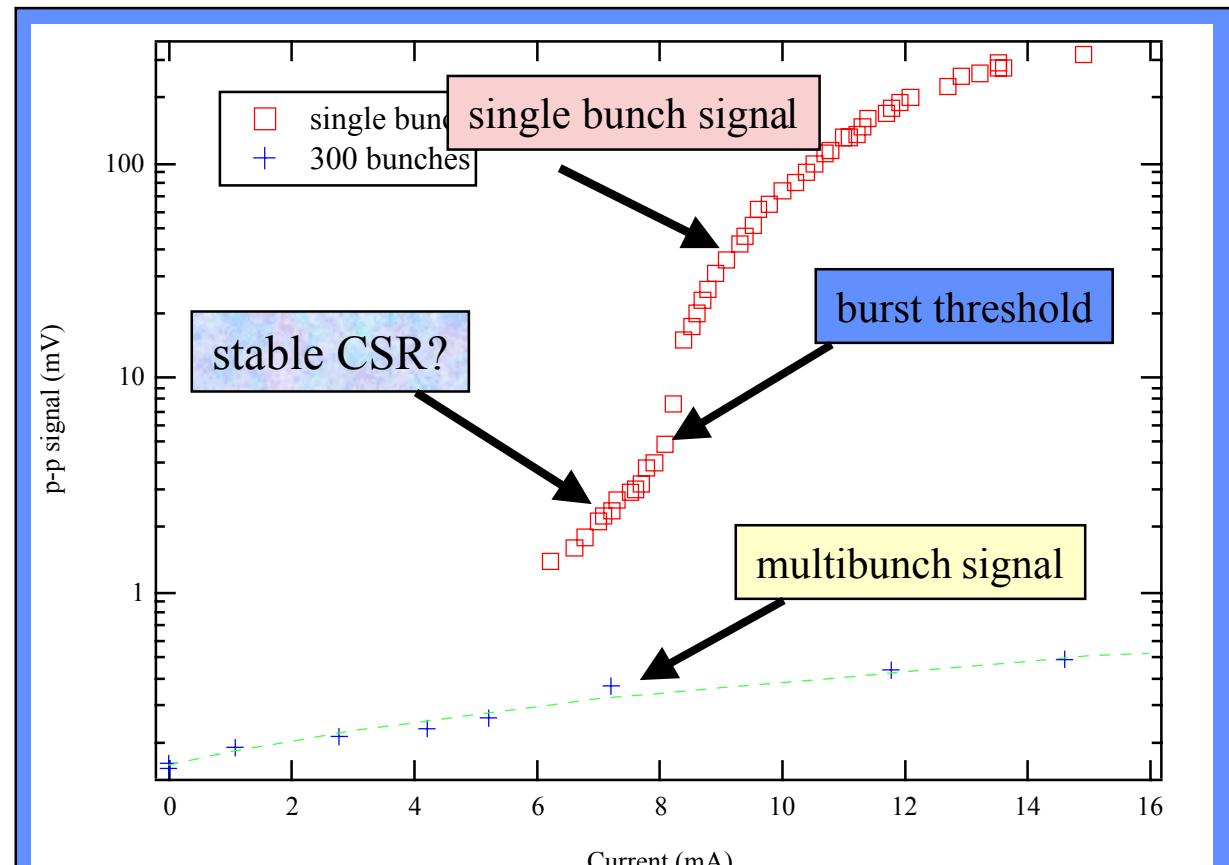
Coherent enhancement

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Compare single and multibunch signal to look for coherent enhancement

- factor 600 enhancement at 15 mA (probable detector saturation)
- SB signal appears larger than MB at same current. Slope also larger (steady CSR?)
- threshold at 4.9 mA in mm-wave rcvr, 8.5 mA, and 9.3 mA in bolometers at 1.5 GeV

Is it possible to use
this light?



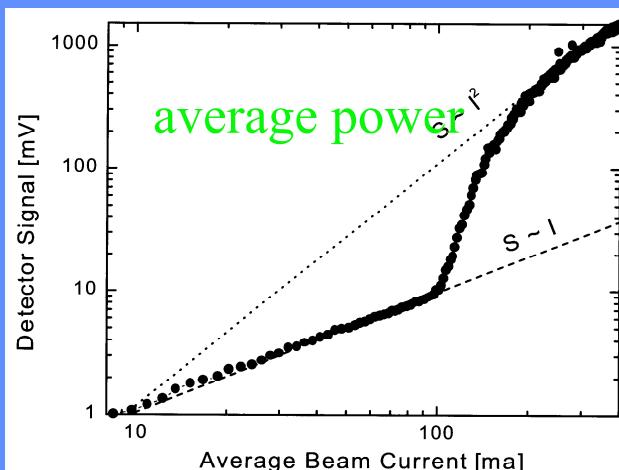
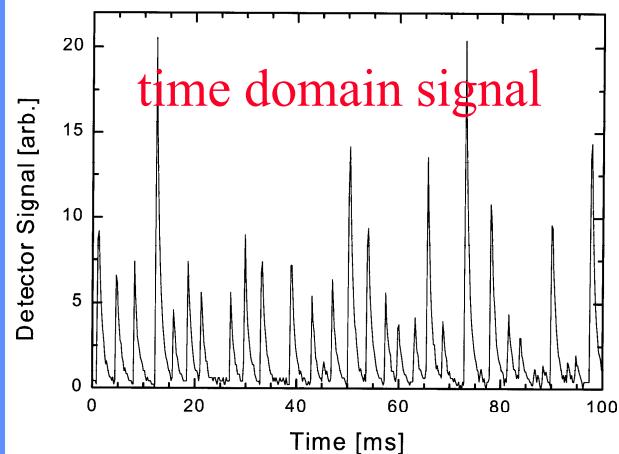
Average single bunch and multibunch signals vs. current in 0.5-2 mm bolometer. Below bursting threshold, single bunch signal has up to a factor 12 enhancement over multibunch signal is larger for single bunch.



Observations of bursting CSR

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NSLS-VUV Ring (G. Carr, et. al., NIMA 463 (2001) 387-392)



Similar behavior observed at:

- SURF-II/NIST (U. Arp, et. al., Phys. Rev. STAB, 4, 054401, 2001)
- MAXLab/MAX-I (Å. Anderssen. et. al., Proc. SPIE 3775, 1999, 77.)
- Bessy-II (Abo-Bakr, et. al., submitted to PRL, Oct. 2001., EPAC 2000.)

Bursting instability appears to be fairly universal. Is this a limit for achieving steady coherent emission?

Sub-microwave instabilities



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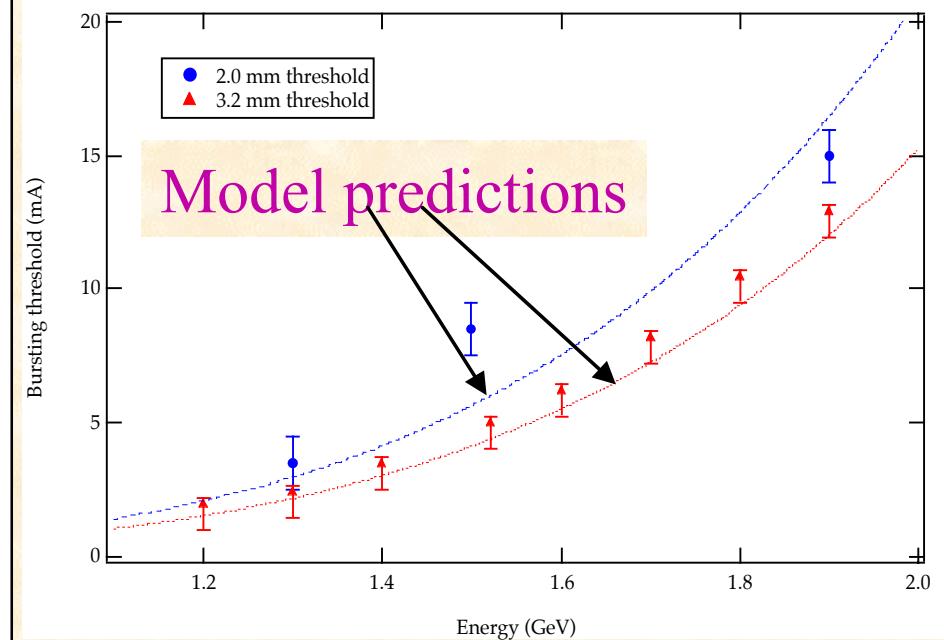
Unexplained CSR bursts in the far-IR have been observed at several rings:

- CSR microbunching model proposed by Heifets and Stupakov . Mechanism similar to SASE FEL process.
- ALS studies are the first to link the CSR bursts to bunch instabilities driven by the radiation impedance in a storage ring.
- This result gives us confidence that we can avoid this in a dedicated ring.

Detectors

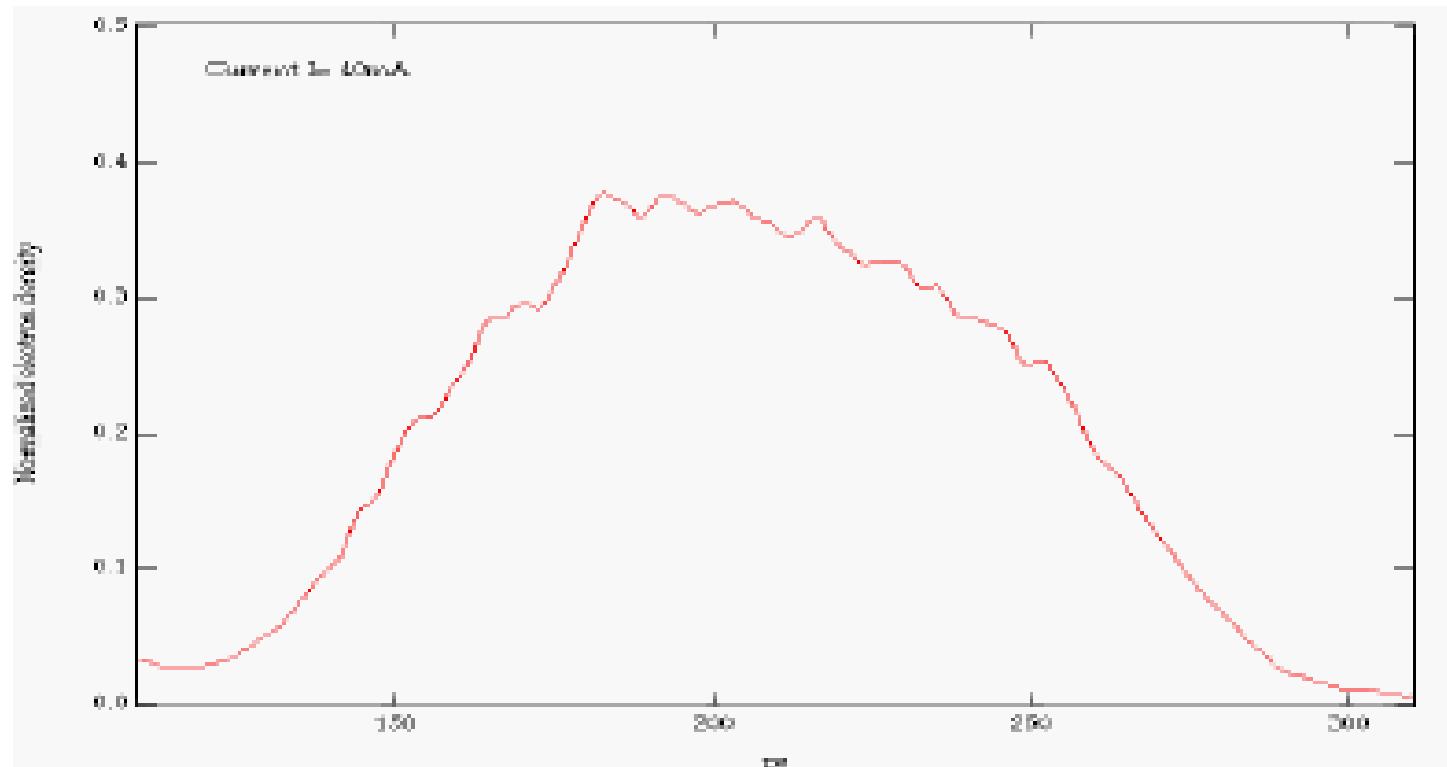
- mm-wave receiver- 3.2 mm (94 GHz), not able to see incoherent SR, < 1 nsec time response, room temperature
- LHe cooled silicon bolometer, BW 0.5-2 mm, sensitive to incoherent SR at low current,
- LHe bolometer, BW 0.1-1 mm (?), spectrometer available up to 0.5 mm

ALS studies show first confirmation of CSR driven sub-microwave instability



Life as an electron bunch

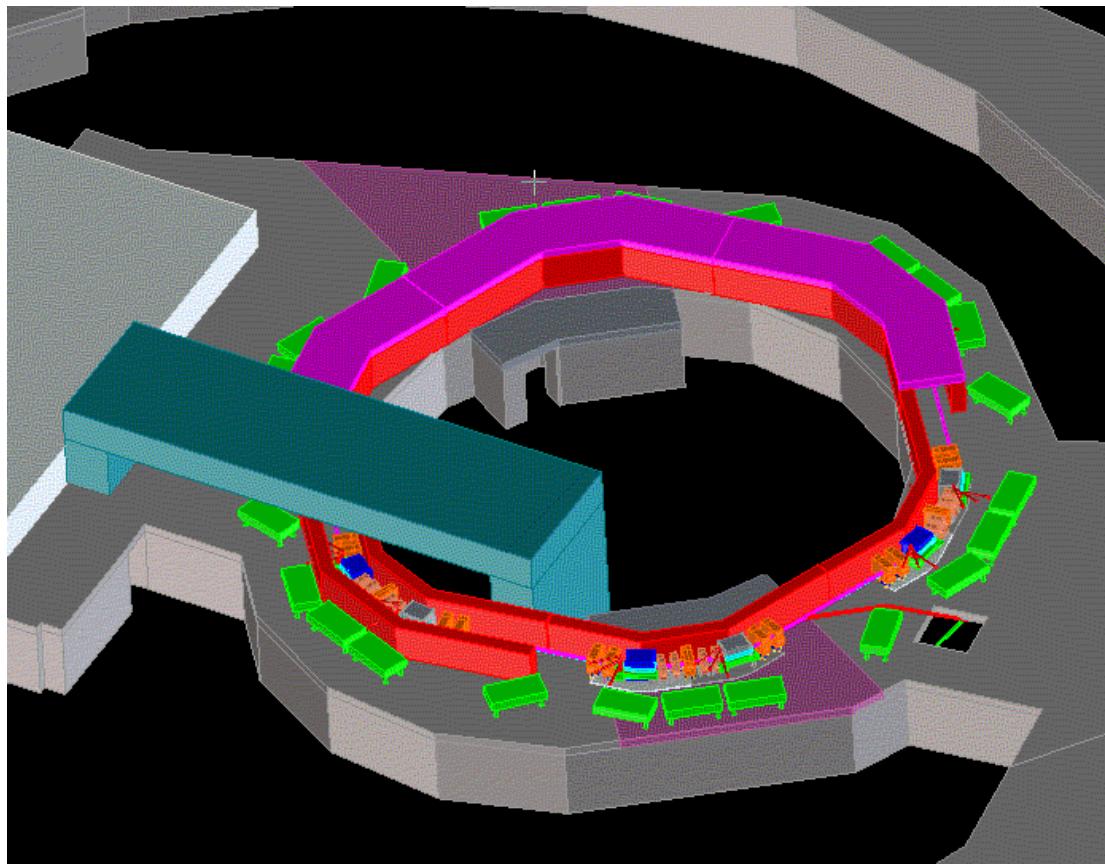
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Correlation
of ripples
with IR
burst not
yet made

Measure longitudinal bunch profile vs. time using a streak camera. Single bunch operation with current from 40 mA/bunch to 30 mA/bunch. Movie made from 200 microsecond (~300 turns) sequences captured on SC at ~1 second intervals.

A dedicated source of IR SR



**Beam Line Experiments Located on
Top of the Booster Shielding**

- “Free” full energy (700 MeV) injector-ALS main ring fills at 8 hour intervals.
- Adequate floor space for IR beamline experiments.
- Stable surface supporting ring and beamline.
- SR collection optics optimized for IR

An internal project review in March 2002 strongly recommended focussing effort on producing a source of coherent SR.

Summary and Plans

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- CSR promises to provide a unique and powerful source or synchrotron radiation in the far-IR.
- Evidence of steady CSR has been obtained at Bessy-II and possibly ALS.
 - further ALS studies.
 - complete analysis of Bessy-II results.
- ALS measurements of CSR bursts show first confirmation of instabilities driven by radiation impedance
- strong collaborations have been formed
 - Bessy-II (experimental studies)
 - SLAC (Warnock and Venturini simulation studies)